Troubleshooting AD problems

Different wastewaters require variations in the anaerobic digestion process. **Paul Lavender** of Aqua Enviro details experiences of troubleshooting and optimisation of full-scale plants in a range of industrial applications

Anaerobic digestion (AD) has become increasing popular for the treatment of industrial wastewater over the past 20 years and many variations of this technology have been developed to enhance process performance and efficiency. The main benefit of AD over aerobic treatment is reduced power requirements, because aeration is not required, and minimal sludge production.

Additionally, the potential to generate both heat and energy from the biogas makes this technology particularly appealing for those industries that have effluents with higher concentrations of organic contaminants and higher temperatures.

Between 20-30 new industrial AD plants were built each year in the EU through the 1990s. With the recent steep increases in energy costs and requirements to reduce GHG emissions, AD technologies are likely to become even more prominent. The common operating problems of aerobic treatment processes, such as bulking and foaming in the activated sludge process, are well documented and easily observed.

While anaerobic processes are generally robust and reliable, where operating problems do occur these can often be difficult to observe and monitor. For successful implementation and operation, both the wastewater characteristics and process conditions in anaerobic reactors must be considered. As with aerobic treatment systems, there is a range of technologies available:

- Lagoons – simple low-loaded systems where the hydraulic retention time dictates the sludge retention time
- Contact process – completely mixed reactor followed by a clarifier to re-circulate the biomass back into the process
- Fixed film – also known as an AD filter. This utilises a fixed-carrier material to retain biomass in the systems
- Fluidised bed system – biomass immobilised on a fluidised carrier material such as sand or pumice

But, the two most popular processes are the up-flow anaerobic sludge blanket (UASB) and the expanded granular sludge bed (EGSB). These are used in more than 80% of the plants installed worldwide between 1997 and 2000 (Franklin 2001).

High loading rates and consequent small footprint are the major advantage of the UASB and EGSB processes. They rely on the development of a well-settling granular sludge under continuous up-flow conditions with a gas/sludge/liquid (GSL) separator being employed to help disassociate gas bubbles from the sludge particles and retain these in the process. The difference between them is that the EGSB operates at a higher up-flow rate, fluidising the bed and improving wastewater/sludge contact. A variation on these processes is the hybrid system, which has a granular sludge bed in the lower part of the reactor with a carrier material mounted in the upper-part section. This carrier material retains biomass for further treatment capacity as well as providing a physical barrier to act as a GSL separator retaining the granular sludge.

The most easily treatable wastewaters are those that are low in solids, and are mostly comprised of a simple readily biodegradable substrate such as sugars/starches or short-chain volatile fatty acids (VFAs). The nature of the organic compounds, and how readily biodegradable these are, has a big impact on the required hydraulic retention time, and hence the reactor size required to treat a given wastewater (see figure 1).

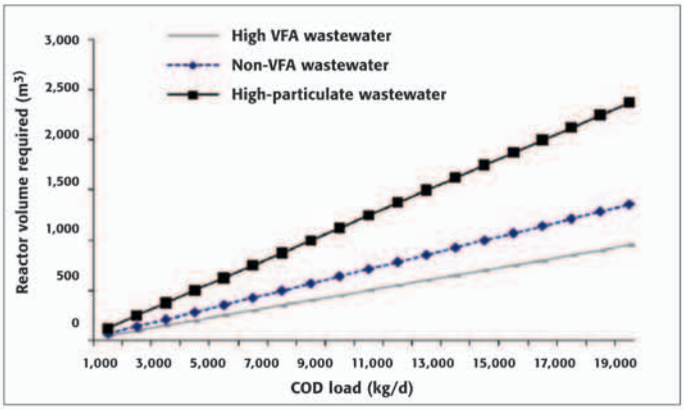

Figure 1: Comparison of reactor volume required for different wastewater types, based upon typical maximum loadings for high VFA, low VFA and high-particulate wastewaters of 20, 14 and 8g COD/l/d respectively

This figure shows that slowly biodegrading wastewaters may require a reactor up to twice as large as that for a readily biodegradable wastewater, thus massively increasing the capital cost of the plant. Where wastewater is more slowly biodegradable – either because of more complex organic compounds or a higher particulate fraction – then it is desirable to incorporate a pre-acidification step to condition the wastewater and reduce the required size of the reactor.

This was confirmed at a UK pharmaceutical plant where a UASB reactor failed to establish sufficient methanogenic activity until a pre-acidification stage was retrofitted to condition the wastewater.

Experience has shown the pre-acidification step can be rendered ineffective where a lack of upstream balancing causes high fluctuations in pH and/or flow. This kills/inhibits the acidifying biomass, or provides insufficient retention time for treatment – between 12 and 24 hours is usually required. Additionally, it is desirable to try and retain the biomass in the acidification tank to ensure sufficient treatment, and so consideration must be given to the outlet configuration for the tank.

The AD process is sometimes thought of as being less resilient to toxicity than aerobic processes. But, this is not necessarily the case as these processes have been used to successfully treat chemical industry wastewaters of varying toxicity, such as formaldehyde-rich effluents (Zoutberg, 1997). The relative inhibition of metals in the anaerobic processes is very compound specific, with certain metals being potentially problematic, while others have a much higher threshold for inhibition in AD than in aerobic processes (see table 1 on facing page).

Where poor methane production is experienced, it is much more common for this to be associated with problems with the process conditions, rather than toxicity. A lack of nutrients also has the potential to impair the process, although the requirements are significantly lower than in aerobic treatment. The maximum BOD:N:P ratio for anaerobic digestion is typically quoted as 500:5:1, compared with 100:5:1 in aerobic treatment. The lower nutrient requirements of AD processes can represent a significant cost saving when treating nutrient-deficient wastewaters.

To maximise the potential of a digester it is important that all upstream processes are optimised as a high influx of solids, or any other materials, can have a number of damaging effects to the process. Due to the short

Metal	Activated sludge	Anaerobic digestion	Nitrification
	Concentration (mg/l)		
Cadmium	10-100	0.02	–
Chromium (cr^{6+})	1-10	1-50	0.25
Chromium (cr^{3+})	50	50-500	0.05-0.5
Copper	1	1-10	0.05-0.5
Iron	100-1,000	5.0	–
Lead	0.1	–	0.5
Magnesium		1,000	50
Mercury	10	–	–
Manganese	0.1-5.0	1,365	–
Nickel	1.0-2.5	2.0	0.25
Silver	5.0	–	–
Zinc	0.08-0.5	0.08-10	5-20

Table 1: Comparison of typical inhibitory concentrations in activated sludge and anaerobic digestion systems

hydraulic retention times in UASB and EGSB systems, influent solids are unlikely to degrade through hydrolysis and these can accumulate in the reactor. This can reduce the capacity of the process as well as potentially block the inlet distribution system and outlet pipes and weirs.

The importance of the upstream treatment processes operating well was demonstrated at a paper mill where poor performance of the primary system was allowing a high quantity of paper fibres into the reactor. Microscopic analysis showed that the sludge granules were becoming

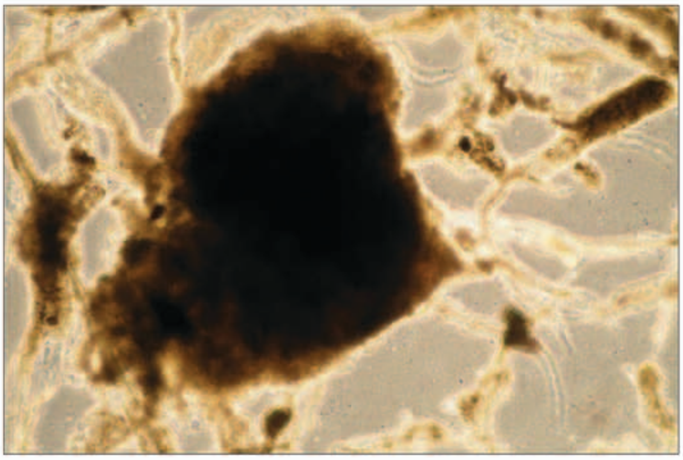

Figure 2: A sludge granule from a UASB plant trapped among paper fibres

entwined in the fibres (see figure 2). When gas bubbles formed these could not disassociate, and so the sludge granules were carried to the surface.

This initially blocked all the outlet weirs and ultimately led to a massive loss of the blanket.

Another potential problem is posed by fats, oils and greases (FOGs), and while these can enhance gas yields from conventional anaerobic sludge digesters, they represent a significant problem in wastewater digesters. FOGs are generally not hydrolysed in the absence of methanogenesis (Zeeman et al 2001), so a pre-acidification stage is largely ineffective at converting these into more readily biodegradable compounds.

Once in the digester there is usually insufficient residence time for much of the FOG to degrade, thus causing a number of negative impacts.

The presence of hydrophobic FOG affects the disassociation of the gas bubbles, allowing stable air bubbles, called micelles, to form in and around the sludge granules (figure 3). ▶

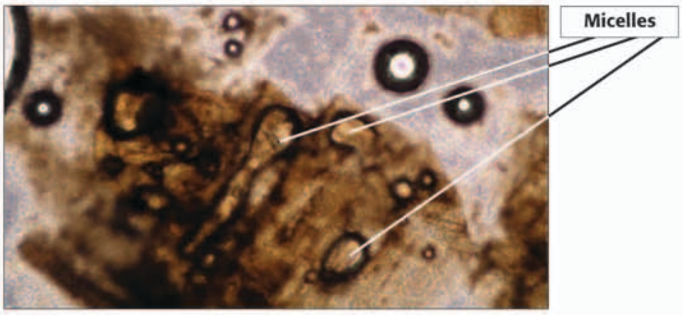

Figure 3: Stabilised gas bubbles, or micelles, present within and around sludge granules due to fats, oils and greases

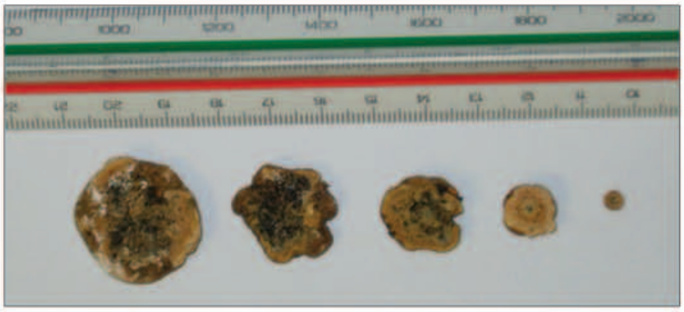

Figure 4: Large, hardened balls of fat formed around AD granules at a food- processing site

This again causes significant losses of the sludge blanket.

In extreme cases, FOG has actually coated the sludge granules. This has been observed at a food-processing site.

Over time, the problem became more pronounced with the granules becoming bound together until golf-ball-sized clusters of fat were observed around the anaerobic granules (see figure 4). Samples from the digester showed that there was virtually no granular sludge bed remaining due to the presence of the FOGs. A DAF unit had to be installed prior to the digesters to allow a granular sludge bed to be able to form. With the right upstream processes in place, a correctly designed AD plant should be highly effective for most industrial applications. The biomass can cope with intermittent loads with treatment quickly resuming, even after shutdowns of up to nine months.

It has also been found that short-term shock loads have little impact, with a sustained period of overloading being required before significant sludge loss is observed. A simple monitoring regime of influent and effluent COD and VFAs, as well as monitoring of gas quantity and quality, is usually sufficient to control and optimise the process. Visual and microscopic examination of the biomass is also useful to assess the health of the biomass. Anaerobic processes operate well on simple, readily biodegradable, substrates. Where more complex wastewaters exist, anaerobic technology can be successfully applied as long as the necessary upstream treatment processes are in place.

A pre-acidification step can be effective at conditioning complex wastewaters to enhance the AD process, but it must be ensured that sufficient upstream balancing capacity is available for this to operate correctly. Pilot plant testing can be invaluable in assessing the treatability of a wastewater and determining pre-treatment/conditioning requirements.

A pilot trial should provide all the necessary design data for a full-scale application. Once a well-designed AD plant is commissioned, it should provide a robust and flexible treatment solution with minimal monitoring requirements. Additionally, this should provide the opportunity for significant environmental and financial benefits through the use of the biogas for heating and power generation.